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Combination of Advanced Reservation and Resource Periodic Arrangement for RMSA in EON with Deep Reinforcement Learning

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***Abstract*—The Elastic Optical Networks (EON) provide a solution to the massive demand for connections and extremely high data traffic with the Routing Modulation and Spectrum Assignment (RMSA) as a challenge. In previous RMSA research, there was a high blocking probability because the route to be passed by the K-SP method with a deep neural network approach used the First Fit policy, and the modulation problem was solved with Modulation Format Identification (MFI) or BPSK using Deep Reinforcement Learning. The issue might be apparent in spectrum assignment because of the influence of Advanced Reservation (AR) and Resource Periodic Arrangement (RPA), which is a decision block on a connection request path with both idle and active data traffic. The study's limitation begins with determining the modulation of m = 1 and m = 4, followed by the placement of frequencies, namely 13 with a combination of standard block frequencies 41224–24412, so that the simulation results are less than 0.0199, due to the combination of block frequency slices with spectrum allocation rule techniques.**

***Keywords*—Elastic Optical Networks (EON), Routing Modulation and Spectrum Assignment (RMSA), Advanced Reservation (AR), Resource Periodic Arrangement (RPA)**

I. Introduction

TECHNOLOGY is undeniably crucial in today's world, and everything is dependent on it.

Due to the rising need for connections and particularly intense data traffic, optical networks are a viable solution to satisfy high traffic demand and data capacity demands, one of which emerges as a new network that can solve these problems, called Elastic Optical Networks (EON) [1].

Elastic Optical Networks (EON) are very promising as the internet path of the future, but they have weaknesses in spectrum fragmentation, as it can increase the blocking probability and reduce the performance of connection requests [1]. In addition to the limitations of spectrum fragmentation, the Elastic Optical Networks (EON) has advantages in terms of the use of spectrum resources if it optimizes optical paths and changes metric parameters [2]. An Elastic Optical Networks (EON) that works dynamically can outperform an Elastic Optical Networks (EON) that employs fixed-rate, mixed-line-rate, and bandwidth-variable transponder technologies [3]. However, in order to be more optimal, Elastic Optical Networks (EON) should use the appropriate modulation type selection [4]. Because modulation technology for Elastic Optical Networks (EON) can affect power consumption, the cost of multiple devices integrated by optics [5], and the complexity of the algorithm when the Elastic Optical Networks (EON) path uses clustering technique parameters [6]. The use of appropriate modulation techniques in Elastic Optical Networks (EON) can maximize the performance of Elastic Optical Networks (EON) networks, one of which is based on WDM [7], Because optimal network performance means that it can send data streams at very high speeds through various internet services [8], in addition to proper modulation techniques known as Modulation Format Identification (MFI), that can reduce service data flow errors in connection requests [9].

Spectrum optimization in Elastic Optical Networks (EON) can improve spectrum usage, but it has not had the desired effect since it might impair the quality of internet network services [10]. The quality of internet network services is defined by two primary characteristics: excellent connection recovery during delays and minimal resource utilization when the spectrum to be assigned is continuous and contiguous [11]. This is a factor to consider in Elastic Optical Networks (EON), which can reduce the number of frequency slots to a minimum Frequency Slots (FS) [12].

Regenerator sharing, adaptive modulation, routing, and spectrum assignment (RMRS) algorithms can maximize spectrum sharing between optical lines by taking into consideration the Routing Modulation and Spectrum Allocation (RMSA) capabilities of each transmission passing over the optical line [13]. This has an impact on the Orthogonal Frequency Division Multiplexing (OFDM)-based Elastic Optical Networks (EON), which is seen as a promising solution for optical networks in the next generation, as this network helps to meet the required connection demand capacity by selecting the range of spectrum slots to be used [14]. Elastic Optical Networks (EON) time delays have an impact on frequency and time domain optimization, as well as static routing and Routing and Spectrum Allocation (RSA) assignments for bulk data transfer requests [15]. One option to avoid this is to use a first-last-fit spectrum determination policy to split the spectrum divisions into capacities capable of reducing spectrum fragmentation [16].

Determining spectrum allocation regulations might influence future increases in internet traffic and pricing. As a

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result, network operators have a difficult task since they must employ multi-period network planning approaches in order to improve the quality of service in the operator's network [17]. For example, the use of first-last-fit (LF) spectrum allocation in Elastic Optical Networks (EON) can lower the blocking probability [18]. This is due to its extensive capabilities and versatility. Meanwhile, as cloud computing and server data centers have increased in popularity, a new type of demand has evolved known as advance reservation request services [19]. Because this type of service may result in unanticipated bandwidth use during connection requests, Modulation Format Identification (MFI) as a determinant of entropy values is required [20]. The blocking probability can be reduced by selecting the first fit spectrum determination strategy, multiplying the number of frequency slots by 130, and combining standard frequency blocks 13. Additionally, the proposed frequency block combination of 13 is limited to the numbers (2.5)-(4.5), but this study has not discussed the BPSK modulation function with modulation code with m = 1 and m = 4, which will affect the low blocking probability [21].

In this paper, we compare modulation codes with m = 1 and m = 4 to existing algorithms. The following summarizes the motivation for research: First, we evaluate large-frequency slot assignment schemes with m = 1 and m = 4 modulation codes that can result in a low blocking probability. Next, we examine how modulation codes of m = 1 and m = 4 affect low entropy, as well as frequency slots with idle request states, the same bandwidth, and upper-limit optical network routes (light paths).

II. Literature Review

A. Code Modulation-based AR-RPA Simulation

The route selected based on K-SP will be modulated with values of m = 1 and m = 4 using BPSK. The modulated route will be assigned to each slot 12 using a combination of Slot Frequency 41224-22441 or can achieve the shortest distance by simulating formulas from AR and RPA or can be formulated (1) as follows [21]:

$$S_t = \left\{o, d, \text{r}, \tau \left\{ \left\{ Z_k^{1,j}, Z_k^{2,j} \right\} | J \in [BC], Z_k^3, Z_k^4, Z_k^5 \right\} | \text{K} \in [1, K] \right\} \quad (1)$$

B. Blocking Probability

The RMSA Deep Reinforcement Learning (DRL) framework was created, which takes into consideration the features of the issue in RMSA, and there are basically various calculations that can be made, such as the number of frequency slots, modulation rate, signal range, and route grouping [22]. The number of frequency slots can be formulated as follows (2) [22].

$$n = \left[\frac{b}{m.C_{GRID}^{BPSK}} \right] \quad (2)$$

The notion of WDM-based EON may be expressed as n, as the allocation of needed frequency slots; b, as bandwidth; and m, as modulation. This study included BPSK, QPSK, 8QAM, and 16QAM modulations [22]. However, in this study, modulation with the kind of BPSK that matches the data rate C_{GRID}^{BPSK} that will be served was discovered, and the spectrum slots will be split by the available slot index and busy, or termed First Fit. There are various spectrum assignment policies, but only the first fit policy is studied [22].

The KSP topology in the EON network may be created using the Yen K Short Path (KSP) algorithm, which is used to discover route candidates in connection requests and assign frequency slots based on the selection of the shortest route (KSP) (3) [22]:

$$S_t = \left\{o, d, \tau \left\{ \left\{ Z_k^{1,j}, Z_k^{2,j} \right\} | J \in [1, J], Z_k^3, Z_k^4, Z_k^5 \right\} | \text{K} \in [1, K] \right\} \quad (3)$$

The path from data receipt to destination d may be described by S_t, but the data is obtained from the source o and destination d.The state sequence of the source and destination receivers can be called the link τ with the interpretation of the order of the source path named j and the destination called K, and the distance between the source and destination sequence called $Z_k^{1,J}, Z_k^{2,J}$ [22].

C. RMSA-based AR Request for Connection

In studying the interpretation of certain RMSA algorithms in 2019, Li et al. devised an AR-based RMSA algorithm approach. The study's findings provided spectrum resources from either a local or global perspective, with a reduced blocking probability than the prior strategy [23].

The frequency cell is inactive because the spectrum resource, which consists of the frequency cell, is busy. The idle time frequency cell in row f and column t has the following state or can be formulated (4) as follows [23]:

$$S_{f,t} = \begin{cases} 1, & Cell\ idle \\ 0, & Cell\ busy \end{cases} \quad (4)$$

All frequency cells on the frequency block are idle, and the time frequency block is available [23], resulting in an approach to AR requests with an indeterminate start time [23]. AR requests with an unspecified start time and specified duration can be formulated (5) as follows [23].

$$r = (s, d, C, D, t_a, t_{es}, W) \quad (5)$$

Connection service request r contains source request s and destination d, connection requests will be provided with data capacity in Gbit/s C for each request coming t_a including the earliest start time of the request t_{es} and a measure of flexibility at the beginning of time W [23]. The proposed algorithmic approach can be created as a reference for a framework for optimization of an agent in an algorithm based on a Machine Learning (ML) theory to provide a more reliable connectivity in times of increasing connection [24].

D. Optimization of Parameter Modulation

In 2020, Zhou et al. used Routing Spectrum and Allocation (RSA) to solve the complex problem of with Machine learning (ML), modeling environtments in computers that can be understood and calculated [25].

The learning results of the algorithm in 2020 li et.al conducted four simulations with different modulation code levels to get the optimal setting of the modulation of a connection request. His research aims to solve a complex problem of obtaining a small blocking probability value. The simulation results showed, that the blocking probability with modulation values at different levels has an impact on connection requests. When the traffic density is low, it will get the lowest blocking probability with m = 1. When the traffic density is moderate, the algorithm gets the lowest blocking probability with m = 3. And when the traffic density is high, the algorithm gets the lowest blocking probability with an m = 4 value [26]. Due to the flexible nature of Elastic Optical Networks (EON), it is effective to use spectral resources for optical communication by allocating the minimum bandwidth required for network connections [27].

Optimization of parameter modulation is taken into account in the potential rate for the arrival of which a probability will be obtained using the Poisson distribution [27], so that it can be symbolized by the Poisson distribution P(λ) [28].

E. RMSA-based Resource Periodic Arrangement (RPA)

The proposed algorithm reduces the probability of bandwidth blocking as well as compares it with several benchmarks. This solution uses the most widely used policy to set the dynamic frequency of connection requests. The RPA strategy aims to produce better spectrum resources [29].

In the RPA strategy, connection requests can be served with an SFB combination in theory that a single block of standard frequencies is considered to be a combination of SFB or denoted by BC, so it can be formulated (6) as follows [29].

$$BC = (I_{first}, N_B) \tag{6}$$

I_{first} is the first frequency standard blocking index in BC and N_B is the number of standard blocking frequencies in BC [29].

F. Route Distance Calculation based on K-SP

There are several important things to consider when designing elastic optical networks, particularly the adequacy of the spectrum in each path that aims to get enough services for the entire network in the user's so-called spectrum assignment [30]. The spectrum's adequacy is directly proportional to the size or size of the topology to be used [30]. In 2020, Jara et.al., used the Spectrum Assignment rules to solve problems in the ring topology (Concentric Ring). Spectrum allocation can be equipped with alternative routing fix routing [30], to calculate source and destination paths based on conus topology or can be seen in the formula (7) as follow [31]:

$$R = 2r.arcsin\sqrt{sin^2\left(\frac{Lat_{j+1}-lat_j}{2}\right) + cos\left(lat_j\right).cos\left(Lat_{j+1}\right)sin.^2\left(\frac{Log_{j+1}-log_j}{2}\right)} \tag{7}$$

In 2021, Khan et.al., used Routing Spectrum and Allocation (RSA) to complete alternative routing fixes with a fixed, potential routing and spectrum allocation scheme [32], as data traffic density can be compared to several benchmarks. In 2021, Liu et.al., used RMSA to solve the problem of reducing the probability of bandwidth blocking and improving spectrum utilization best against the previous research benchmark [33]. In 2021, Safari et al. used a Deep Convolutional Neural Network formulation to augment allocated effectiveness in networks with significant topological differences [34]. There is a method for estimating the effectiveness of a connection to a user in networks with significant topological complexity, so we used K-SP to approach the creation of distance simulations using the Haversine formula approach and data range of source and destination with topology CONUS [35]. The topology modifications are based on the algorithm Chen et al. use to select Standard Frequency Blocks (SFB) from the availability of Frequency Slots (FS) based on the distance between nodes at the start and end time using the Deep Reinforcement Learning (DRL) method. Because of the possibility of distributed group work, the traffic is used as a framework for a computation process that runs continuously to maintain moving traffic [36].

III. RMSA-BASED AR-RPA ALGORITHM DESIGN

A. The ARRPA Algorithm Method.

The determination of each FS (Frequency Slot) is based on the experience of an agent, consisting of time for in-service learning in each connection request. NSF and CONUS topology routes will be simulated with a frequency placement of 13 that can be seen in Algorithm 1.

Algorithm 1 The ARRPA algorithm with m = 1, m = 4

Input: SFB determination with values of m = 1, m = 4.
Output: RMSA determination resulting in comparison of blocking probability, reward, value, and entropy.
Step 1: Routing and Spectrum Slot.
1. Calculating a slot with equation 2.
2. Using equation 3 to calculate slots.
Step 2: Allocation and Modulation of Spectrum.
1. The use of slots on frequencies uses equation 4 and 5.
2. Use of SFB 13 with a combination of 41224-22441 (NSF and CONUS Topology) equations 6.
Step 3 : Calculate the RMSA that will result in Action, Reward, Value, and Entropy.
1. Calculating the conus route by equation 7
2. Initiation of the RMSA process step with equation 1 using the Asynchronous Advantage Actor Critic (A3C) Deep Reinforcement Learning Model

IV. SIMULATION PERFORMANCE

The NSF and CONUS network topology will select a standard parameter of frequency blocking placement consisting of busy and available states, then the number of slots of 130 frequencies. The frequency blocking flow will be grouped with a frequency placement number.

A. Topology Configuration

This research uses NSF and CONUS topology. The NSF and CONUS topology consists of 14 nodes selected based on the shortest and longest distances that can be seen in Figure 1.

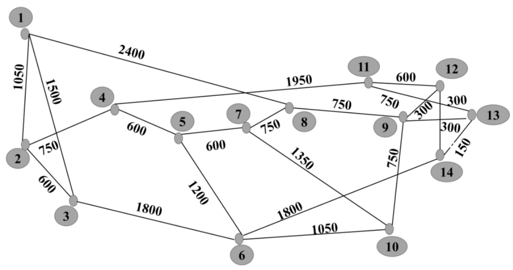

Fig. 1. Topology NSF [22]

In Figure 1, routes are based on distance segmentation. The lowest distance is on route positions 9-12, 9-13, and 12-14, while the longest distance is on route 1-8, with an average distance of 484 km.

In Figure 2, the lowest distance is at the route position from 2–3, while the longest distance is on Route 1-3, with an average distance of 677 km.

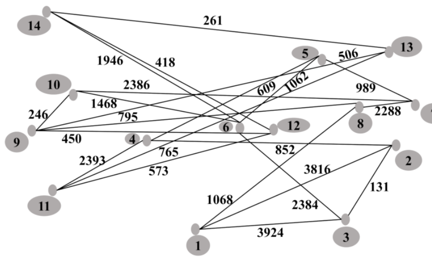

Fig. 2. Topology CONUS [21]

B. Code Modulation in Comparison to Current Algorithms

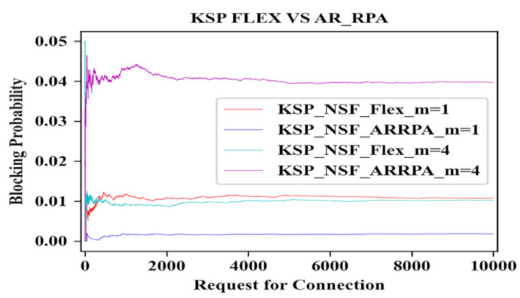

Fig. 3. K-Short Path Topology NSF

Figure 3 shows a graph of the relationship between blocking probability and connection requests in 10,000 simulation experiments. The results of the comparison of variables give a slightly decreased result in the flex m = 1 algorithm on the connection request was to 26 by 0.003846, while m = 4 on the request of connection to 2 increases by 0.05. This is due to not allocating spectrum for routing to the closest distance. The results of the ARRPA algorithm in some tests gave quite good results, namely m = 1 on the connection request to 49 of 0.002041, but if m = 4 on request 3, the higher by 0.033333 due to the alternative routing fix route with a fixed routing scheme. The results of the NSF topology ARRPA algorithm become the maximum value benchmark for connection requests on the EON network.

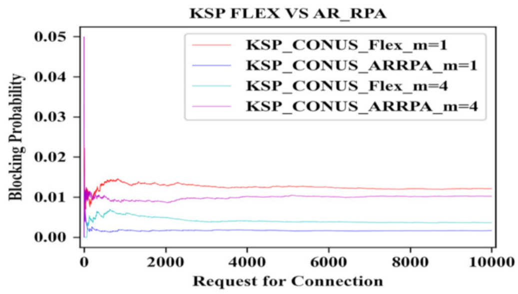

Fig. 4. K-Short Path Topology CONUS

Figure 4 shows a graph of the relationship between blocking probability and connection requests in 10,000 simulation experiments. The results of the comparison of variables gave poor results in the flex algorithm at m = 1 when the connection request was to 3 by 0.0333, and m = 4 on the connection request to 74 dropped by 0.001351 because the optimal routing performance had to choose the shortest route. The results of the ARRPA algorithm in several tests gave quite good results, namely at m = 1 in the request for connection to 5 by 0.02 while m = 4 in connection request 2 increased by 0.05 due to As a result, this result became the highest benchmark for connection requests in the EON network's CONUS topology.

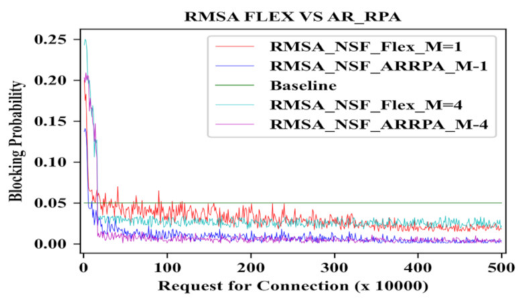

Fig. 5. Blocking Probability Topology NSF

Figure 5 describes a graph of the relationship between blocking probability and connection requests. Experiments using simulations of 5 million obtained slightly decreased results in the flex algorithm with m = 1 when the connection request was to 10 by 0.2 and increased when m = 4 by 0.243 due to a reduction in the probability of blocking bandwidth that did not use the shortest distance. The results of the ARRPA algorithm obtained good results because they were lower than the baseline at 16 requests when m = 1 was

0.031 and higher at m = 4 by 0.127 due to the increase in the best spectrum utilization with the determination of the shortest path. The results of comparing the 2 algorithms compared to the baseline obtained quite good results of 0.05 due to choosing the right slot frequency, so it was concluded that complementing the accommodation of allocated demand and increasing spectrum utilization in spectrum allocation is important because it affects the Quality of Transmission (QoT).

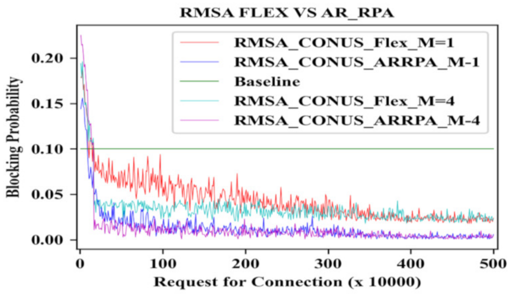

Fig. 6. Blocking Probability Topology CONUS

Figure 6 describes a graph of the relationship between blocking probability and connection requests. Experiments using simulations of 5 million obtained slightly decreased results in the flex algorithm when the connection request was increased to 10 with m = 1 by 0.101 and m = 4 increased by 0.108 due to the identification of the modulation format between transmissions that did not use the shortest distance. The ARRPA algorithm results in the connection request to 10 with m = 1 by 0.08, while if m = 4 in the request, by 0.132, because it has the same wavelength as the determination of the shortest path. The results of comparing the 2 algorithms compared to the baseline obtained quite good results of 0.1 due to choosing the right slot frequency. So, it was concluded that the need for connectivity by checking the slot frequency assignment scheme can reduce the possibility of high blocking.

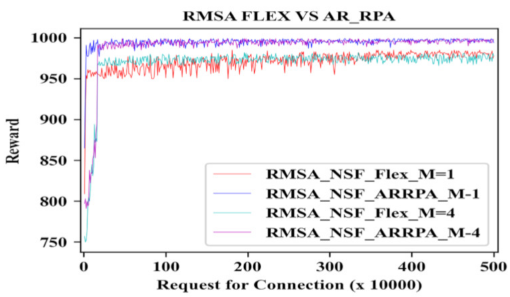

Fig. 7. Reward Topology NSF

Figure 7 explains the graph of the relationship between rewards and connection requests with a simulation of 5 million. The comparison results showed that the slightly decreased results in the flex algorithm when m = 1 in requests of 13 increased by 947 and m = 4 decreased by 894 due to the complexity of routing. The results were quite good in the ARRPA algorithm at m = 1 connection request to 13, showing an increase of 977, whereas m = 4 decreased by 875 due to using spectrum allocation and routing, thus concluding that the use of spectrum reservations can be a solution to the complexity of routing and spectrum allocation.

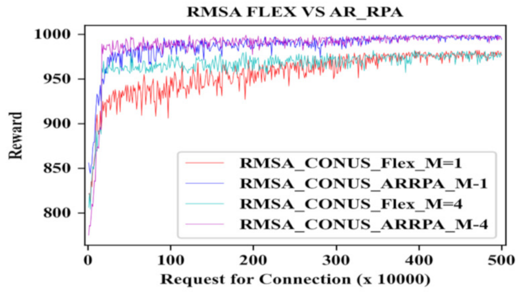

Fig. 8. Reward Topology CONUS

Figure 8 explains the graph of the relationship between rewards and connection requests with a simulation of 5 million. The comparison results showed that the slightly decreased result in the flex algorithm when m = 1 connection request to 6 decreased by 849 and m = 4 experienced an increase of 852 due to the availability of spectrum with an index of less than 13, and a fairly good result in the ARRPA algorithm on connection requests to 6 with m = 1 indicating an increase of 873 and m = 4 decreased by 807 due to choosing spectrum slots indexed 41224-24412, so it was concluded that the ARRPA algorithm is more likely to handle the addition of connection requests.

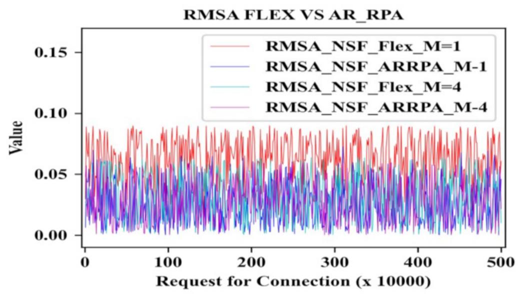

Fig. 9. Value Topology NSF

In Figure 9, the relationship between the value of the value variable and the connection request is described with a simulation of 5 million. The comparison result gets higher in the Flex algorithm when m = 1 in the connection request to 24 by 0.08568 and the decrease when the value of m = 4 is 0.058396 due to high connectivity needs. The results were quite good in the ARRPA algorithm on connection requests to 24 with m = 1 of 0.022784 and further dropped when the request was to 24 with m = 4 of 0.012806 due to choosing a modulation format in network routing, so it can be concluded that using RMSA to maximize connectivity needs in wide-area networks.

In Figure 10, the relationship between the value of the value variable and the connection request is described with a simulation of 5 million. The result of the comparison was high in the Flex algorithm at m = 1 when the connection request to 22 was 0.078 and dropped further when the value of m =

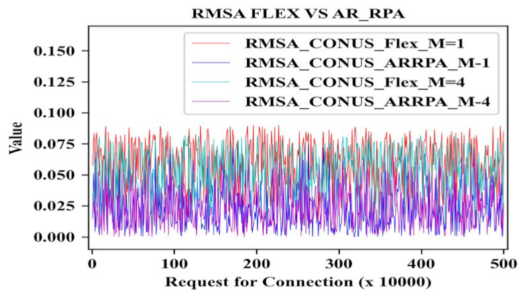

Fig. 10. Value Topology CONUS

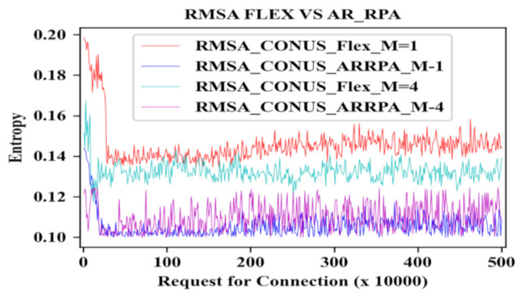

Fig. 12. Entropy Policy Topology CONUS

4 was 0.073 due to the complexity of the connection request time. The results are quite good in the ARRPA algorithm on the connection request to 22 when the value of m = 4 is 0.018 and m = 1 is 0.039 due to the influence of the lower limit in the transmission link with the modulation value m = 4, so it can be concluded that the ARRPA algorithm is more efficient in increasing the need for connection requests.

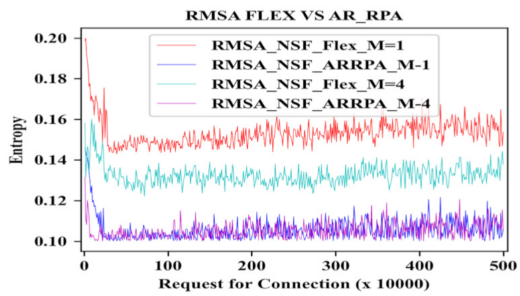

Fig. 11. Entropy Policy Topology NSF

In Figure 11, show a graph of the relationship between entropy variables and connection needs with a simulation of 5 million. Due to the existence of alternative routing fix routes, the comparison results were slightly higher in the Flex algorithm when m = 1 in the connection request to 10 by 0.1688718 and further decreased at that value by 0.1542328. The results obtained for the ARRPA algorithm at m = 4 of 0.1028521 and m = 1 on connection requests to 10 of 0.1192029 because it uses Spectrum Assignment rules to solve problems in the topology path scheme can be concluded that by choosing a modulation format in network routing that affects quality, flexibility, and scalability.

In Figure 12, shows a graph of the relationship between entropy variables and connection needs with a simulation of 5 million. The comparison results were slightly higher in the Flex algorithm when m = 1 in the connection request to 14 by 0.1772408 and further decreased when the value of m = 4 was 0.1190072 due to spectrum fragmentation. Therefore, the standard combination slot in this algorithm is still not ideal. The results obtained using the ARRPA algorithm in the connection request are quite good because it chooses the position of the slot with the modulation value m = 4, so it can be concluded that the amount of information to be distributed is better and does not cause higher blocking of the connection request.

In Table I describe a comparison of the calculations of the ARRPA algorithm with the results of previous studies. Some of the variables calculated are KSP, blocking probability, and entropy. The results of the KSP ARRPA algorithm CONUS topology are lower with m = 1 by 0.0980068 while m = 4 by 0.00071 compared to the NSF topology with m = 1 by 0.00027 and m = 4 by 0.0014 due to the determination of wavelengths and link routes between transmissions based on BPSK modulation. The blocking probability result of the ARRPA algorithm of the NSF topology is lower with m = 1 of 0.0136 and m = 4 of 0.0293 compared to the CONUS topology with m = 1 of 0.0199 and m = 4 of 0.0284 due to maximum routing performance. The entropy results of the ARRPA algorithm NSF topology are lower with m = 1 by 0.0060 and m = 4 by 0.0055 compared to the CONUS topology with m = 1 by 0.0061 and m = 4 by 0.0067 because it defines the BPSK modulation with the value of m = 1, and the combination standard slot is 13, so it can be concluded that grouping the intersection of block frequency slices with the same type of traffic as the spectrum allocation rule method with minimal time change for spectrum fragmentation can affect probability blocking as well as connection requests.

TABLE I
COMPARISON OF THE RESULTS TO PREVIOUS WORK

Ref	K-SP	BP	Entropy
[4]	10^{-1}	-	-
[20]	-	-	1
[21]	0.0980068	0.0199	0.0061
[22]	0.065	0.06	0.1
[23]	-	0.0204	-
[29]	-	0.04	-
[33]	-	0.08	-
[36]	-	0.0445	-
AR-RPA. NSF m=1	0.00027	0.0136	0.006
AR-RPA. CONUS m =4	0.00071	0.0284	0.0067
AR-RPA. NSF m=4	0.0014	0.0293	0.0055

V. Conclusion

In this paper, it was concluded that the Routing Modulation and Spectrum Assignment (RMSA) problem for connection requests on the network of Elastic Optical Networks (EON) concluded that the blocking probability would be lower if it set a Number Frequency Slot (NFS) of 13, which is where the Standard Frequency Blocks (SFB) 41224–24412 and the First Fit policy compared to the previous calculation with determining the modulation of m = 1. There is a slightly higher influence compared to the previous calculation, which can be seen in Entropy due to the use of Modulation Format Indentification (MFI) in determining the modulation of m = 1 as a determinant of the entropy value. The simulation results were lower than 0.0199 and 0.0061 from previous studies because it could be determined that combining block frequency slices with the same type of traffic as the spectrum allocation rule technique by minimizing the influence of spectrum fragmentation could affect blocking capabilities as well as connection requests.

Research suggestions for future research to examine the effects of QoT on the quality of software and hardware of a device on EON and the use of traffic distribution using QPSK, QAM, and 16 QAM Modulation with an NSF 2 until NSF 12 and the Last Fit First spectrum assignment policy.

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